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(54) **DOWNHOLE TOOLS WITH ELECTRO-MECHANICAL AND ELECTRO-HYDRAULIC DRIVES**

(75) Inventors: **Olof Hummes**, Wadersloh (DE); **Michael Koppe**, Lachendorf (DE); **Volker Krueger**, Celle (DE); **Sven Krueger**, Winsen (DE); **Matthias Meister**, Celle (DE)

(73) Assignee: **Baker Hughes Incorporated**, Houston, TX (US)

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(51) **Int. Cl.**

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E21B 4/00	(2006.01)
E21B 41/00	(2006.01)
E21B 23/00	(2006.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
CPC E21B 41/00; E21B 2023/008; E21B 23/00
USPC 166/65.1, 66.5, 66, 6, 381, 217, 50, 166/66.6; 175/61, 106, 76, 99, 57, 92; 310/87, 26, 306, 309, 311; 318/264–266, 272, 275, 277, 282, 286, 318/466–469, 626; 335/215
See application file for complete search history.

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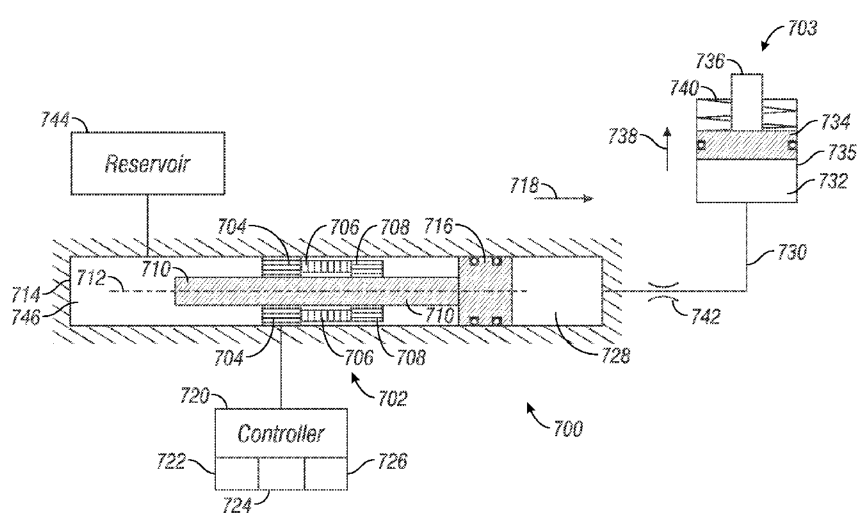
Primary Examiner — Jennifer H Gay
Assistant Examiner — George Gray
(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

An apparatus to be conveyed into a wellbore. The apparatus includes a housing configured to be conveyed downhole and a drive member located in the housing. The apparatus further includes a drive unit configured to actuate movement of the drive member by selectively coupling to the drive member, wherein the coupling of the device to the drive member is controlled by applying an energy to a selected material in the device.

21 Claims, 5 Drawing Sheets



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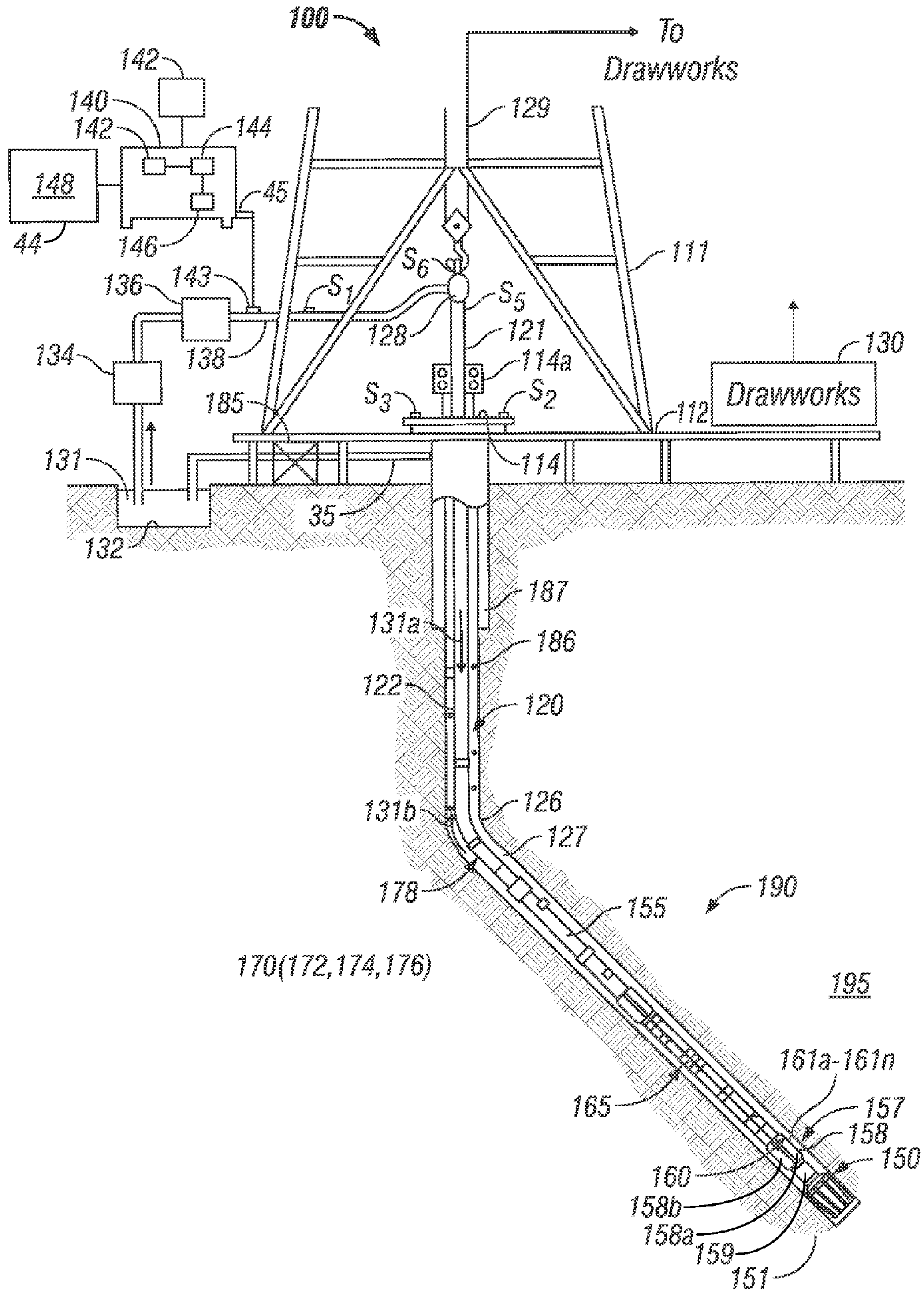
100
To
Drawworks
142
140
142
144
148
45
44
146
111
S6
S5
136
143
S1
128
121
134
138
114a
130
Drawworks
185
S3
S2
112
131
114
35
132
187
131a
186
122
120
131b
126
127
178
190
155
170(172,174,176)
195
161a-161n
165
157
158
150
160
158b
158a
159
151

FIG. 1

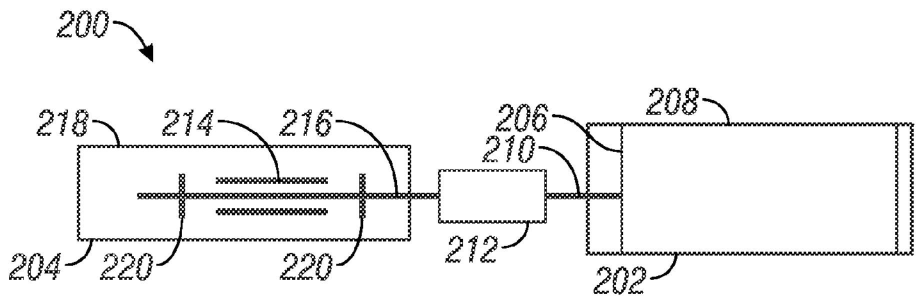

FIG. 2

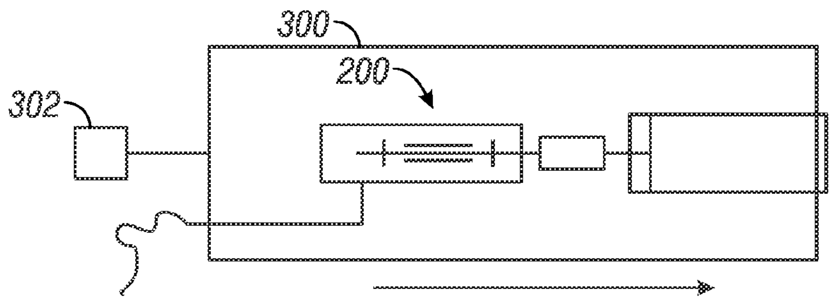

FIG. 3

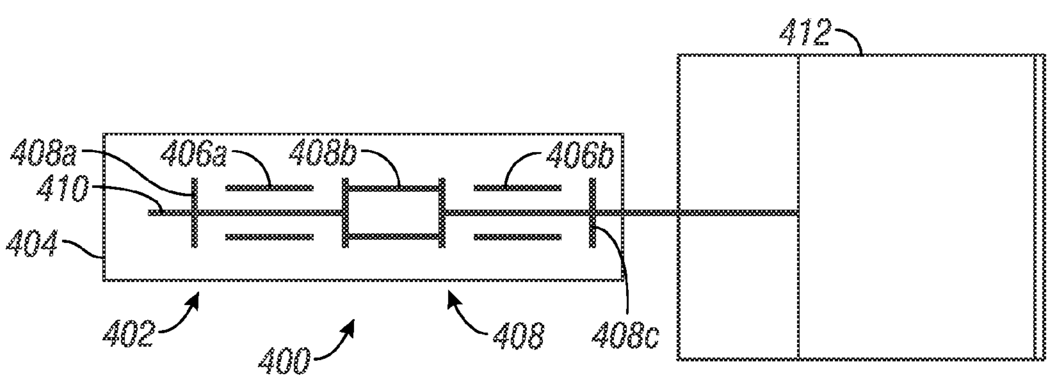

FIG. 4

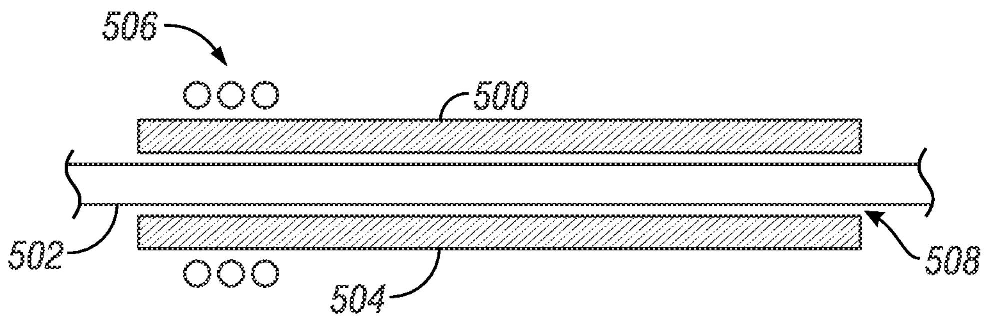

FIG. 5

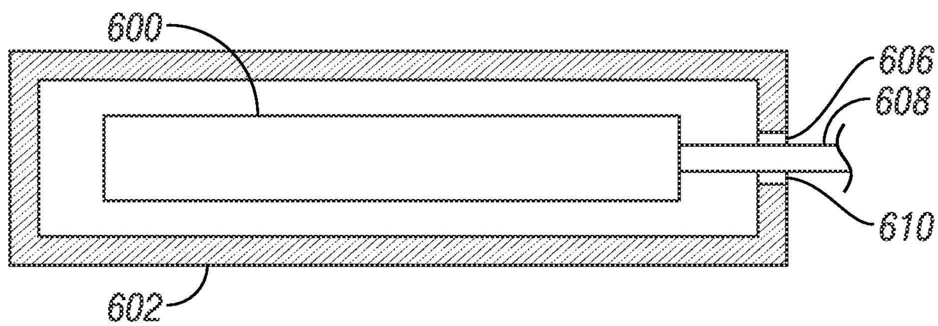

FIG. 6

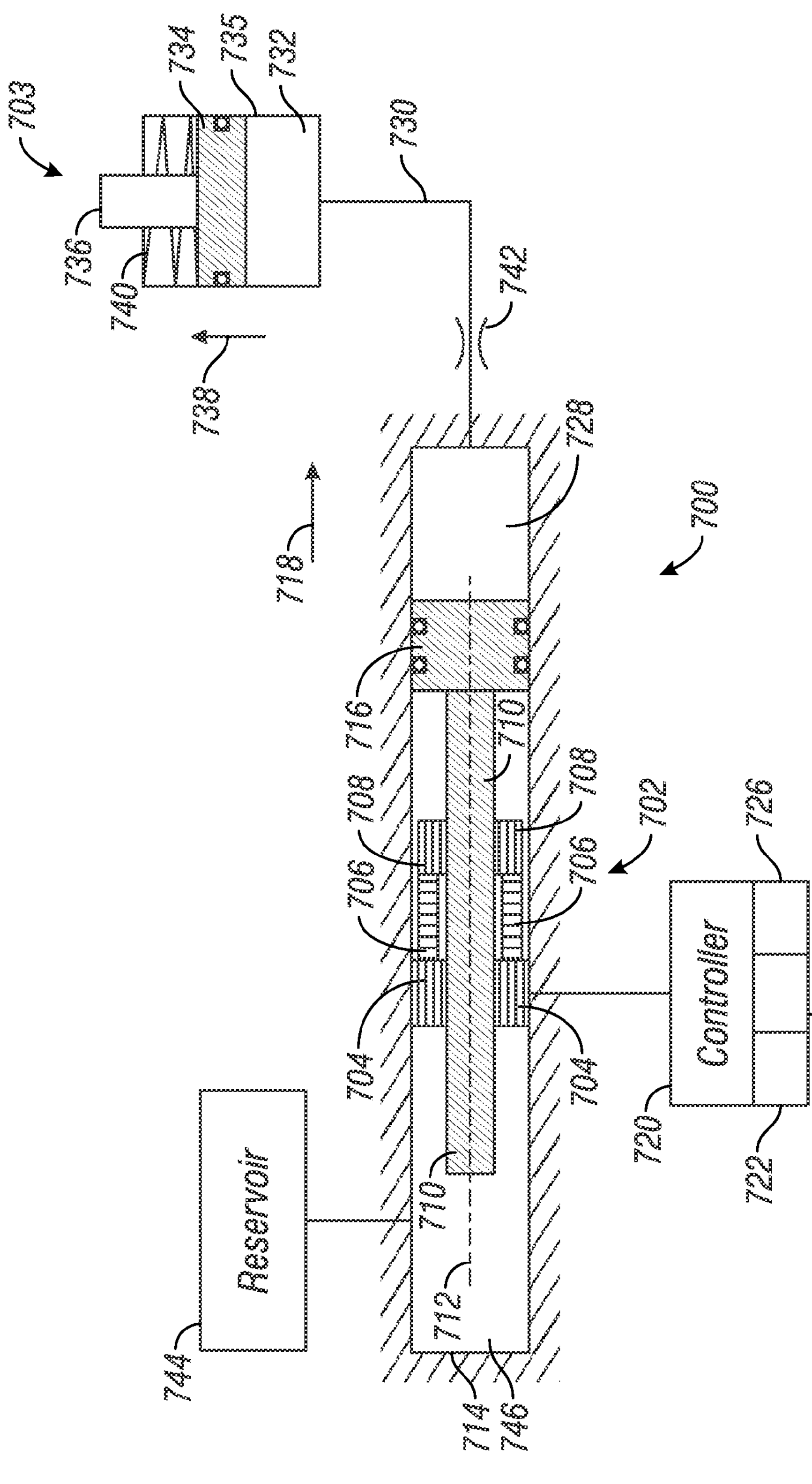
703
734
735
732
730
736
740
742
738
728
700
718
716
710
708
706
702
704
726
Controller
720
722
724
Reservoir
744
712
714
746

FIG. 7

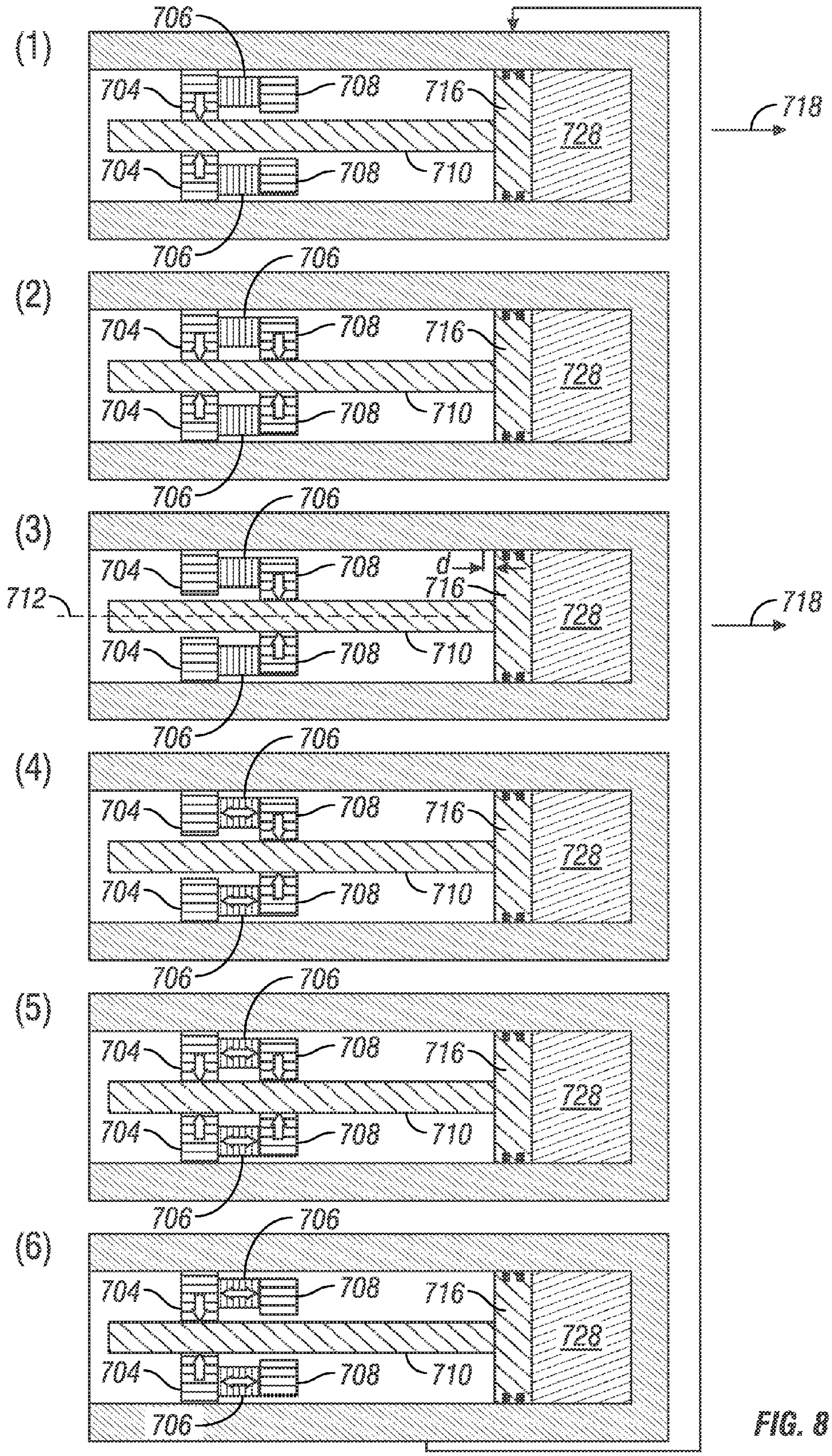

FIG. 8

DOWNHOLE TOOLS WITH ELECTRO-MECHANICAL AND ELECTRO-HYDRAULIC DRIVES

CROSS REFERENCES TO RELATED APPLICATIONS

This application claims priority from the U.S. Provisional Patent Application having Ser. No. 61/289,674 filed Dec. 23, 2009

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

The disclosure relates generally to drive units or devices for use in downhole tools.

2. Description of the Related Art

Oil wells (also referred to as "wellbores" or "boreholes") are drilled with a drill string that includes a tubular member having a drilling assembly (also referred to as the "bottom-hole assembly" or "BHA") at an end of the tubular member. The BHA typically includes a variety of tools and sensors that provide information relating to a variety of parameters relating to drilling operations ("drilling parameters"), behavior of the BHA ("BHA parameters"), and parameters relating to the formation surrounding the wellbore ("formation parameters"). A large number of wellbores include curved sections. A BHA used to drill non-vertical sections of the borehole often includes a steering unit to steer the drill bit along a desired direction. One type of steering unit includes a number of force application members that are moved radially outward to apply pressure on the borehole wall. A drive unit or an actuator is used to move the force application member. Formation evaluation tools used in both a BHA and in wireline tools utilize devices that include a drive unit to operate a piston to drawdown fluid from the formation. Other tools used in BHA and wireline logging tools also utilize drive units in conjunction with other devices to extract fluid from the formation for testing and analysis of the extracted fluids. Other devices in downhole tools that utilize drive units may include valves, pistons and the like. Moveable stabilizer blades, bit controllers, coring tools, mud pulse tools, and other moving components may also be configured to use drive units.

Drive units used for expanding force application members typically incorporate motor driven piston pumps that provide pressurized fluid to expand or move a piston. The pressure level is controlled by a nozzle arrangement in conjunction with pump rotational speed or torque or by a solenoid proportional valve. Certain other drive units are based on a motor-driven ball screw spindle, driving a first piston of smaller diameter to provide pressure to a larger secondary piston.

Such drive units are relatively mechanically complex and also utilize filters, flow restrictors, shut-off valves, etc. for fail-safe operations and pressure relief valves for overload protection. The complexity and components of these drive units may require frequent maintenance and be costly to manufacture. The disclosure herein provides drive units that are relatively small and address some of the above-noted problems.

SUMMARY

In one aspect, an apparatus to be conveyed into a wellbore is provided, wherein the apparatus includes a housing configured to be conveyed downhole and a drive member located in the housing. The apparatus further includes a drive unit configured to actuate movement of the drive member by selectively coupling to the drive member, wherein the coupling of the device to the drive member is controlled by applying an energy to a selected material in the device.

In another aspect, an apparatus conveyed into a well borehole for conducting a downhole operation is provided. The apparatus includes a mechanically-actuated device adapted for conveyance by a work string, the mechanically-actuated device being used at least in part for conducting the downhole operation and a magnetostrictive linear actuator coupled to the mechanically-actuated device for selectively actuating the mechanically-actuated device. In addition, the magnetostrictive linear actuator includes a support structure to compensate for a borehole parameter.

BRIEF DESCRIPTION OF THE DRAWINGS

For detailed understanding of the present disclosure, references should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

FIG. **1** is an elevation view of a drilling system including a downhole tool according to an embodiment of the present disclosure;

FIGS. **2-4** show a downhole tool according to several embodiments of the present disclosure;

FIG. **5** is a cross-section to illustrate embodiments of the present disclosure utilizing matched material characteristics;

FIG. **6** is a cross-section to illustrate embodiments of the present disclosure utilizing active cooling and/or Dewars canisters;

FIG. **7** is a cross-section schematic illustrating an embodiment of an electro-hydraulic drive system, according to one embodiment of the disclosure; and

FIG. **8** shows a sequence of operations for the electro-hydraulic drive system shown in FIG. **7**.

DESCRIPTION OF THE DISCLOSURE

FIG. **1** is a schematic diagram of an exemplary drilling system **100** that includes a drill string having a drilling assembly attached to its bottom end that includes a steering unit according to one embodiment of the disclosure. FIG. **1** shows a drill string **120** that includes a drilling assembly or bottom-hole assembly ("BHA") **190** conveyed in a borehole **126**. The drilling system **100** includes a conventional derrick **111** erected on a platform or floor **112** which supports a rotary table **114** that is rotated by a prime mover, such as an electric motor (not shown), at a desired rotational speed. A tubing (such as jointed drill pipe) **122**, having the drilling assembly **190** attached at its bottom end extends from the surface to the bottom **151** of the borehole **126**. A drill bit **150**, attached to drilling assembly **190**, disintegrates the geological formations when it is rotated to drill the borehole **26**. The drill string **120** is coupled to a drawworks **130** via a Kelly joint **121**, swivel **128** and line **129** through a pulley. Drawworks **130** is operated to control the weight on bit ("WOB"). The drill string **120** may be rotated by a top drive (not shown) instead of by the prime mover and the rotary table **114**. Alternatively, a coiled-tubing may be used as the tubing **122**. A tubing injector **114***a* may be used to convey the coiled-tubing having the drilling assembly attached to its bottom end. The operations of the drawworks **130** and the tubing injector **114***a* are known in the art and are thus not described in detail herein.

A suitable drilling fluid **131** (also referred to as the "mud") from a source **132** thereof, such as a mud pit, is circulated under pressure through the drill string **120** by a mud pump **134**. The drilling fluid **131** passes from the mud pump **134** into the drill string **120** via a desurger **136** and the fluid line **138**. The drilling fluid **131***a* from the drilling tubular discharges at the borehole bottom **151** through openings in the drill bit **150**. The returning drilling fluid **131***b* circulates uphole through the annular space **127** between the drill string **120** and the borehole **126** and returns to the mud pit **132** via a return line **135** and drill cutting screen **185** that removes the drill cuttings **186** from the returning drilling fluid **131***b*. A sensor S_1 in line **138** provides information about the fluid flow rate. A surface torque sensor S_2 and a sensor S_3 associated with the drill string **120** provide information about the torque and the rotational speed of the drill string **120**. Tubing injection speed is determined from the sensor S_5, while the sensor S_6 provides the hook load of the drill string **120**.

In some applications, the drill bit **150** is rotated by only rotating the drill pipe **122**. However, in many other applications, a downhole motor **155** (mud motor) disposed in the drilling assembly **190** also rotates the drill bit **150**. The ROP for a given BHA largely depends on the WOB or the thrust force on the drill bit **150** and its rotational speed. The mud motor **155** is coupled to the drill bit **150** via a drive shaft disposed in a bearing assembly **157**. The mud motor **155** rotates the drill bit **150** when the drilling fluid **131** passes through the mud motor **155** under pressure. The bearing assembly **157**, in one aspect, supports the radial and axial forces of the drill bit **150**, the down-thrust of the mud motor **155** and the reactive upward loading from the applied weight-on-bit.

A surface control unit or controller **140** receives signals from the downhole sensors and devices via a sensor **143** placed in the fluid line **138** and signals from sensors S_1-S_6 and other sensors used in the system **100** and processes such signals according to programmed instructions provided from a program to the surface control unit **140**. The surface control unit **140** displays desired drilling parameters and other information on a display/monitor **142** that is utilized by an operator to control the drilling operations. The surface control unit **140** may be a computer-based unit that may include a processor **142** (such as a microprocessor), a storage device **144**, such as a solid-state memory, tape or hard disc, and one or more computer programs **146** in the storage device **144** that are accessible to the processor **142** for executing instructions contained in such programs. The surface control unit **140** may further communicate with a remote control unit **148**. The surface control unit **140** may process data relating to the drilling operations, data from the sensors and devices on the surface, data received from downhole, and may control one or more operations of the downhole and surface devices.

The BHA may also contain formation evaluation sensors or devices (also referred to as measurement-while-drilling ("MWD") or logging-while-drilling ("LWD") sensors) determining resistivity, density, porosity, permeability, acoustic properties, nuclear-magnetic resonance properties, properties or characteristics of the fluids downhole and determine other selected properties of the formation **195** surrounding the drilling assembly **190**. Such sensors are generally known in the art and for convenience are generally denoted herein by numeral **165**. The drilling assembly **190** may further include a variety of other sensors and devices **159** for determining one or more properties of the BHA (such as vibration, bending moment, acceleration, oscillations, whirl, stick-slip, etc.) and drilling operating parameters, such as weight-on-bit, fluid flow rate, pressure, temperature, rate of penetration, azimuth, tool face, drill bit rotation, etc. For convenience, all such sensors are denoted by numeral **159**.

The drilling assembly **190** includes a steering apparatus or tool **158** for steering the drill bit **150** along a desired drilling path. In one aspect, the steering apparatus may include a steering unit **160**, having a number of force application members **161***a*-**161***n*, each such force application unit operated by drive unit or tool made according to one embodiment of the disclosure. A drive unit is used to operate or move each force application member. A variety of wireline tools (not shown) used for logging well parameters subsequent to drilling include formation testing tools that utilize drive units to move a particular device of interest. Various exemplary embodiments drive units made according to this disclosure are described below in reference to FIGS. **2**-**8**. FIGS. **2**-**4** schematically show a downhole tool according to several embodiments of the present disclosure. FIG. **2** illustrates a tool **200** that includes a mechanically-actuated device **202**. The mechanically-actuated device **202** is actuated using a linear magnetostrictive actuator **204**. A linear magnetostrictive actuator provides the benefits of small size, high actuation force and controllability. The device mechanically-actuated device **202** described and shown is a drawdown tool for exemplary purposes only. Any mechanically-actuated tool is considered within the scope of the disclosure. As used herein, the term magnetostrictive actuator means any of a number of actuators using materials exhibiting magnetostrictive properties for an actuating element. The term ferromagnetic material used herein is used as an exemplary material for a magnetostrictive actuator without the exclusion of other materials exhibiting magnetostrictive properties used as an actuating element. A magnetostrictive actuator according to the present disclosure is intended to include any such actuator using any such material exhibiting magnetostrictive properties as an actuating element.

A piston **206** is shown movably housed in a piston cylinder **208**. A piston rod **210** is coupled to one end of the piston **206**, and the piston rod **210** passes through the piston cylinder **208**. The piston rod **210** is translated along its longitudinal axis by the magnetostrictive linear actuator **206**. An optional stroke multiplier **212** may be coupled to the piston rod **210** to increase the stroke of the piston rod **210**. In one aspect, the magnetostrictive linear actuator **204** includes a coil **214** disposed around a magnetostrictive rod **216**. The rod **216** comprises a ferromagnetic material exhibiting magnetostrictive properties. One such material is sold under the trade name "Terfenol-D." Such a material changes shape when exposed to a magnetic field and has been found to be useful for downhole applications. Nickel, cobalt, steel, alloys, and any other suitable material may also be utilized as magnetostrictive materials for the purposes of this disclosure. A support structure **218** includes one or more clamping devices **220** for holding a portion of the magnetostrictive rod **216** in place while an applied magnetic field causes an elongation of the ferromagnetic rod material. The support structure **218** supports the rod **216** and coil **214**. In aspects of the disclosure, the coil **214** forms a portion of the support structure.

In some actuators, the clamping device may include a controllable clamp. Such a controllable clamp may be a pair of controllable clamps. In operation, a first clamp is activated to hold a portion of the rod **216** while a second clamp is activated to release a second portion of the rod **216**. When a magnetic field is applied, the rod **216** elongates through the released clamp. Then, the released clamp is activated to clamp the rod and the first clamp is released. Then the magnetic field is discontinued to allow the first clamped rod portion to move toward the second clamp. This series of actions result in a linear "crawl" of the rod through the actuator.

In other actuators, the clamping device may be a tube through which a magnetostrictive rod passes. The outer rod diameter and tube inner diameter are such that the rod tightly fits within the tube when no magnetic field is applied. A magnetic field is controllably applied along the rod such that a portion of the rod elongates. The elongated rod portion necessarily reduces in diameter and thus extends through the tube while the rod portion without an applied magnetic field remains "clamped" within the tube due to the close tolerance of outer rod diameter to inner tube diameter. As the field passes along the tube, the previously elongated portion resumes its original shape and tight fit within the tube. At the same time, other portions of the rod are undergoing the field-elongation phase of movement. This series of actions results in the rod "crawling" along the tube in a linear fashion.

A downhole environment is typically harsh and some cases the temperature may reach 175 degrees centigrade. Magnetostrictive drive units may not properly operate at such high temperatures. One cause of such inoperability may be that the magnetostrictive rod and support structure clamping mechanism have differing thermal expansion characteristics.

FIG. **3** illustrates an embodiment of a drive unit wherein a tool **200**, substantially as described above and shown in FIG. **2**, is housed within a linearly-extendable housing **300**. The housing **300** may be extended by conventional hydraulic or electromechanical devices **302**, or the housing **300** may be extended by the use of a separate magnetostrictive linear actuator according to the present disclosure. Such a configuration extends the overall linear movement of the tool **200**. Where the tool includes a fluid drawdown device, larger borehole size can be accommodated.

FIG. **4** illustrates a tool **400** that includes a magnetostrictive actuator **402** and a support structure **404**. The actuator **402** includes a first coil **406***a* and a second coil **406***b*. A clamping device **408** includes a first clamp **408***a*, a second clamp **408***b* and a third clamp **408***c*. The second clamp **408***b* includes a center portion made of non-ferromagnetic material through which a magnetostrictive rod **410** passes. The clamps and coils operate substantially as described above to provide linear movement of the rod **410**. The coil pair **406***a*, **406***b* and clamps **408***a*, **408***b* and **408***c* provide extended stroke for the magnetostrictive rod. The linear actuator is used to actuate a downhole device **412**, which may be a formation fluid drawdown device as described above.

In any of the above embodiments, the support structure and magnetostrictive member may be selected to achieve the desired operation even within an extreme borehole environment. In some embodiments, the support structure may be selected from materials having thermal expansion characteristics substantially equivalent to the thermal expansion characteristics of the ferromagnetic material used within the actuator. The support structure may include a ceramic material. In other embodiments, the support structure may include cooling devices or a member to counter the high temperature environment of boreholes.

FIG. **5** is a cross section of a portion of a magnetostrictive actuator according to one embodiment of the present disclosure. The actuator **500** includes a ferromagnetic rod **502** passing through a support structure clamping device **504**. A current-carrying coil **506** causes elongation of the rod **502**. The elongated rod creates a small gap **508** between the rod **502** and clamping device **504**. The clamping device **504** may be one of a plurality of controllable clamping devices being electrically controlled to create the gap **508**. In the embodiment of FIG. **5**, the support structure clamping device **504** may be made using a material having coefficient of thermal expansion ("CTE") that matches the CTE of the ferromagnetic rod **502** (For example, an actuator **500** using a rod having a CTE of about 12 ppm/° C. will further include a support structure **504** manufactured using a low alloy steel having a CTE of about 11 to 12 ppm/° C.). Depending upon the selected ferromagnetic material, the support structure **504** may be made using any number of alloys so long as the CTE of the support structure material matches or substantially matches the CTE of the ferromagnetic material.

Alternatively, the support structure may include cooling elements (passive or active) to reduce the environmental temperature around the actuator. An embodiment of the present disclosure utilizing cooling is shown in FIG. **6**. Shown is a magnetostrictive actuator **600** housed within a cooling device **602**. The cooling device may be a Dewars cooling canister or flask having a port **606** through which an actuating rod **608** passes. An insulating o-ring seal **610** positioned at the port **606** between the rod **608** and cooling device **602** allows the rod to move linearly while maintaining a stable temperature within the local environment of the actuator **600**. The rod **608** is used to actuate a mechanically operated tool as describe above.

Alternatively, the cooling device **602** may be an active cooling element such as a thermoelectric element. In either case, the cooling device **602** creates a local temperature environment for the actuator **600**. The local temperature environment may be established at a much lower temperature than the borehole temperature, thus allowing for a better operation of the actuator **600**. In one aspect, the local temperature environment may be maintained below the Curie temperature of the magnetostrictive material used in the actuator. In one aspect, the local temperature environment may be maintained below a predetermined temperature, the predetermined temperature being determined in part by the CTE of the support structure and the CTE of the magnetostrictive material supported by such support structure.

FIG. **7** is a sectional schematic view of an exemplary embodiment of an electro-hydraulic drive unit or system **700** for use in downhole applications. The drive system **700** includes an electromechanical drive unit **702** and secondary drive unit **703**. In an aspect, the electromechanical drive unit **702** controls flow of hydraulic fluid to the secondary drive unit **703**, thereby providing drive system **700** to move components in a downhole tool. The electromechanical drive unit **702** utilizes piezoelectric members **704**, **706** and **708** configured to expand when activated (when electrical energy is applied to them) and contract when deactivated (the applied electrical energy is removed from them). In one aspect, the piezoelectric members may include piezoelectric stacks. The member **704** is coupled to inside of the chamber **714**, member **706** is coupled to the member **704** and member **708** is coupled to member **706**. The members **704** and **708** are positioned to grip or clamp a drive member or rod **710**, while member **706**, positioned between the members **704** and **708**, is positioned to drive or move the member **708** along direction **718**. The drive member **710** may be moved axially **712** within a housing **714** to cause movement of a piston **716** in the direction **718**.

In the configuration shown in FIG. **7**, when the member **708** is clamping the member **710**, a movement of piezoelectric member **706** in the direction **718** will cause the piston **716** to move in direction **718**, thereby reducing a volume **728** within the housing **714**. A fluid, such as hydraulic fluid, is pressed out of fluid volume **728** and through conduit **730** into a fluid volume **732**, causing piston **734** to move in the direction **738**. The fluid displaces the piston **734**, located in a second housing **735**, causing a drive member **736** to move in direction **738**. In aspects, the fluid movement into volume **732** overcomes the force generated by a biasing member **740** to resist movement in direction **738**. A flow restrictor, such as a nozzle **742**, may be located in the conduit **730** to regulate movement and control backflow of the fluid **732** into fluid volume **728**. As depicted, the drive system **700** may be referred to as a sealed or closed loop system with respect to the flow of fluid used to drive members.

In addition, the drive system **700** may include a compensation reservoir **744** to adjust for volume changes in volume **746** caused by the movement of piston **716**. In an aspect, the piston **716** may be sealed within the housing **714** and coupled to the drive member **710**, wherein the drive member **710** and piston **716** are composed of a suitable rigid and durable material, such as a stainless steel or steel alloy. In one aspect, the drive member **710** is held in position by piezoelectric members **704**, **706** and **708**. The piezoelectric members **704**, **706** and **708** include a material that expands or contracts based on exposure to an electric field. As depicted, the piezoelectric members **704** are coupled to the inner surface of the housing **714**. The members **706** are coupled to the members **704** and **708**. The piezoelectric members **704**, **706** and **708** may each be composed of stacks of piezoelectric material, wherein the stacks are oriented to expand and contract in selected directions. In an aspect, the members **704** and **708** are configured to expand and contract in a direction generally radial or perpendicular to the axis **712**. The members **706** are configured to expand and contract in a direction generally parallel to axis **712**. Although the system **700** is described using piezoelectric members, such members may be made from any other suitable material that may be expanded and contracted as desired. For example, any material that expands or contracts in response to an energy source may be used. In one aspect, magnetostrictive materials may be used, wherein the material is capable of converting magnetic energy into kinetic energy.

A controller **720** may be used to control movement of piezoelectric member **708**. The controller **720** includes a processor **722**, memory **724** and programs **726** used to control movement (expansion and contraction) of the piezoelectric members **704**, **706** to operate the electromechanical device **702**. In another aspect, a programmed microcontroller may be used as the controller **720**. The controller is configured to selectively produce an electric field in the piezoelectric members **704**, **706** and **708**. In an embodiment, the drive system **700** may utilize the electromechanical drive unit **702** to directly control movement of a component of a downhole tool.

The operation of the drive unit **702** is described in reference to FIGS. **7** and **8**. In one aspect, to move the piston **716** forward (in the direction **718**), the procedure may include: energize (radially expand) member **704** to hold drive member **710** (FIGS. **8**, **1**); energize (radially expand) member **708** to hold drive member **710** (FIGS. **8**, **2**); de-energize (release) member **704** from the member **710** (FIGS. **8**, **3**); and energize (linearly expand) member **706** to linearly move the member **710** in the direction **718** by an amount “d” (FIGS. **8**, **4**). The movement of the drive member **710** moves the piston **716** by a distance “d.” To move the piston **716** by another distance: activate (expand) member **704** (FIGS. **8**, **5**) to hold drive member **710**; deactivate (contract) member **708** to release drive member **710** (FIGS. **8**, **6**); deactivate (contract) member **706** to bring it to its original position (FIGS. **8**, **1**); and then repeat the steps shown in FIGS. **8**, **2-8**, **4**. The movement of the piston **716** discharges a certain amount of fluid from chamber **728** into the chamber **732**, which drives the piston **734**, which in turn may move a member **736**. The member **736** may then perform a desired function, such as moving a force application member or driving another desired element in a downhole tool. To move the drive member **710** back to its initial position, members **704** and/or **706** may be expanded so as to hold the drive member **710** in position but allow it to move within the chamber **714**. The biasing member **740** will then cause the piston **734** to move downward, causing the fluid in the chamber **732** to move into the chamber **728** via line **730**, causing the drive member **710** to move in the direction **719**. A control valve **742** in line **730** may be utilized to control the flow of the fluid from the chamber **732** to chamber **728**. The surface area of the pistons **716** defines the force exerted by each such piston.

The above-described process may be described as an “inchworm” or “crawl” movement of the drive member **710** along the axis **712**. The operation of the piezoelectric members **704**, **706** and **708** and the control valve **742** may be controlled by the controller **720**, which may be located downhole or at the surface. The stroke of the drive member **710** may be controlled by the amount of the axial expansion of the member **706**. Cycling or modulating through the above modes may be used to cause an actuation of a member in a downhole tool, such as a steering member or rib or a drawdown piston, etc.

Thus, in aspects, the actuator arrangement may be placed in a housing so as to allow axial displacement of a drive member of basically unlimited length. Achievable forces of the primary drive unit **702** and the required pressure at the secondary piston **734** can be matched by optimizing the length/diameter ratio of the two pistons. Exerted force may be directly derived from the piezo effect, thus allowing a closed loop control of pressure without additional pressure sensors. Axial force may be applied by a defined friction between the clamping members **704** and **708** and the drive member **710**. Further, the surfaces of the components may produce the defined friction used to enable a controlled retraction of the drive member **710** as fluid flows from volume **732** into volume **728**. The surface friction may be designed along with biasing member **740** and nozzle **742** to produce optimized control of the drive system **700**. The design of drive system **700** also may allow for a simple and efficient inherent overload protection, as the drive member **710** could be controlled to simply slip through the clamps until the excess pressure is released. In such way, a pressure relief valve may be eliminated, at the same time eliminating the need for discontinuous operation to replace leakage volumes lost via the pressure relief valve. A flow restrictor may be placed between first and second cylinder to dampen steep pressure peaks, though this may not be necessary in some embodiments.

For reliable operations of force application members, in power-off situations, controlled release of actuator pressure is desired. In the system of FIG. **7**, this would be inherently achieved without the need to drain oil into an additional reservoir, such as via a shut-off valve. The dimensions, expansion characteristics and other properties of the piezoelectric members are chosen so as to provide desired friction factors between the members **704** and **708** and the drive member **710** for reliable operation of the drive unit **702**. The friction chosen is sufficient to transmit the required forces. The materials may be matched to allow defined slippage without surface wear. In one aspect, machined micro-ledges on the surface may be provided for desired friction. Also, relatively fast electronic control may be used to release excess pressure quickly by motion of the drive member **710** or release of clamp forces provided by members **704** and **708**.

In one aspect, the device shown in FIG. **7** provides a compact actuator arrangement having relatively few components. The device also is inherently resilient to overloads conditions and is not prone to internal fluid leakage and thus not prone to discontinuous operation due to need for refills. Also, no external pressure fluid reservoir is needed—only a compensation volume on low-pressure side is used. Pressurized fluid, as used in the configuration of system of FIG. **7**, is generally insensitive to pollution. The complete actuator unit may be built as a sealed unit or a sealed drop-in unit.

The foregoing description is directed to particular embodiments of the present disclosure for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above are possible without departing from the scope of the disclosure and the following claims.

The invention claimed is:

1. An apparatus to be conveyed into a wellbore, the apparatus comprising:

a housing configured to be conveyed downhole;

a drive member located in the housing; and

an actuator configured to actuate linear movement of the drive member to control a downhole device hydraulically via the linear movement of the drive member, the actuator including a first active member coupled to the housing that engages the drive member to bi-directionally hold the drive member in place with respect to the first active member when so engaged and a second active member coupled to the first active member that engages the drive member in alternation with the first active member to move the drive member in a selected direction, wherein the engagement of the actuator to the drive member is controlled by applying an energy to a selected material of the actuator.

2. The apparatus of claim **1**, wherein the selected material comprises a piezoelectric material.

3. The apparatus of claim **1**, comprising a processor configured to control the device.

4. The apparatus of claim **1**, wherein the drive member is configured to control actuation of a steering member of a wellbore tool.

5. The apparatus of claim **1**, wherein the actuator comprises an expanding member and a gripping member configured to selectively couple to the drive member, wherein the expanding member and the gripping member each comprise the selected material.

6. An apparatus conveyed into a well borehole for conducting a downhole operation, the apparatus comprising:

a downhole device adapted for conveyance by a work string, the downhole device being used at least in part for conducting the downhole operation; and

a magnetostrictive linear actuator coupled to the downhole device to control the downhole device hydraulically via the linear movement, the magnetostrictive actuator including a first active member coupled to a housing that engages the drive member to bi-directionally hold the drive member in place with respect to the first active member when so engaged and a second active member coupled to the first active member that engages the drive member in alternation with the first active member to move the drive member in a selected direction, wherein the magnetostrictive linear actuator includes a support structure to compensate for a borehole parameter.

7. The apparatus of claim **6**, wherein the magnetostrictive linear actuator comprises a magnetostrictive material operatively housed within the support structure, the support structure comprising a material having a coefficient of thermal expansion substantially equivalent to the magnetostrictive material.

8. The apparatus of claim **6**, wherein the magnetostrictive linear actuator comprises a magnetostrictive material operatively housed within the support structure, the support structure comprising alloyed materials, each of the materials having a different coefficient of thermal expansion, the alloyed materials having an effective coefficient of thermal expansion substantially equivalent to the magnetostrictive material.

9. The apparatus of claim **6**, wherein the support structure comprises a ceramic material.

10. The apparatus of claim **6**, wherein the support structure comprises a pressurized container pressurized to a surface atmospheric pressure.

11. The apparatus of claim **6**, wherein the support structure comprises a dewars cooling device, the magnetostrictive linear actuator being housed within the dewars cooling device, the mechanically-actuated device being located outside the dewars, the magnetostrictive linear actuator including an actuating rod extending from within the dewars to actuate the mechanically-actuated device.

12. The apparatus of claim **6**, wherein the support structure comprises a structural member and an active cooling device cooling the structural member.

13. The apparatus of claim **12**, wherein the active cooling device includes a thermoelectric cooling element.

14. A method of conducting an operation in a well borehole, the method comprising:

conveying a work string into the borehole;

conducting the operation using a downhole device coupled to the work string;

selectively actuating the downhole device using a magnetostrictive linear actuator coupled to a drive member of the downhole device to control the downhole device hydraulically via a linear movement at the downhole device, wherein the magnetostrictive linear actuator includes a first active member coupled to a housing that bi-directionally engages the drive member to hold the drive member in place with respect to the first active member when so engaged and a second active member coupled to the first active member that engages the drive member in alternation with the first active member to move the drive member in a selected direction; and

compensating for a borehole parameter using a support structure coupled to the magnetostrictive linear actuator, the support structure being adapted to compensate for the borehole parameter.

15. The method of claim **14**, wherein the borehole parameter is temperature, the magnetostrictive linear actuator including a magnetistrictive material operatively housed within the support structure, the support structure comprising a material having a coefficient of thermal expansion substantially equivalent to the magnetostrictive material.

16. The method of claim **14**, wherein the borehole parameter is temperature, the magnetostrictive linear actuator including a magnetostrictive material operatively housed within the support structure, the support structure comprising alloyed materials, each of the materials having a different coefficient of thermal expansion, the alloyed materials having an effective coefficient of thermal expansion substantially equivalent to the magnetostrictive material.

17. The method of claim **14**, wherein the support structure comprises a ceramic material.

18. The method of claim **14**, wherein the support structure comprises a pressurized container pressurized to a surface atmospheric pressure.

19. The method of claim **14**, wherein the support structure comprises a dewars cooling device, the magnetostrictive linear actuator being housed within the dewars cooling device, the mechanically-actuated device being located outside the dewars, the magnetostrictive linear actuator including an actuating rod extending from within the dewars to actuate the mechanically-actuated device.

20. The method of claim **14**, wherein the support structure comprises a structural member and an active cooling device, the compensating further comprising cooling the magnetostrictive linear actuator using the active cooling device.

21. The method of claim **20**, wherein the active cooling device includes a thermoelectric cooling element.

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